perature at which steel is poured, as the properties of the ingot produced are influenced by this factor. The correct measurement of this temperature is difficult; thus, if an optical pyrometer be sighted on the molten stream as it issues from the furnace, black-body conditions are not realised, and the apparent temperature indicated may vary according to the quantity of slag accompanying the metal. Similarly, the layer of cooled slag on the surface of the metal in the ladle prevents the true temperature from being ascertained by optical means. Although an occasional reading may be taken with a sheathed junction of platinum and platinum-iridium alloy, the method could not be used regularly owing to the rapid destruction of the sheath. One proposal made was to encase the wires in a large mass of fireclay, leaving the ends uncovered, so that both touched the molten steel; but it was pointed out that this method would cause a rapid destruction of the wires. In spite of these difficulties much progress has been made by following out definite lines of procedure, such as sighting on a certain part of the molten stream at definite intervals of time during the pouring. Mr. Cosmo Johns and others found it possible, under uniform conditions, to obtain readings varying only by 5° to 10°, which, as the chairman remarked, was a surprising result considering the temperature measured. All the speakers who had attacked this problem agreed that the temperature of open-hearth steel when being poured was about 1600° C., careful determinations by Dr. Hatfield with a thermal junction indicating 1600° to 1625°. Further work in this direction is very desirable, as a trustworthy method would be of the greatest value to the steel-maker.

It is still customary in the pottery industry to gauge the firing temperature by using a set of clays of progressive fusibility, and noting the effects on the separate pieces. The latest developments of this method were described in the paper read by Mr. H. Watkin, one of which consisted in placing the test-pieces across two sloping uprights, ladder fashion, so that the droop or complete fusion of any could be readily observed.

Two new suggestions for measuring temperatures of the nature of 1600° C. were put forward, both of which entailed the use of a fused metal. Dr. Northrup, of Trenton, U.S.A., described an instrument based on the expansion of molten tin, constructed on the same lines as an ordinary thermometer. The bulb and stem were of graphite, and a nickel wire passing through a gland in the top of the stem could be pushed down so as to touch the top of the molten tin, when an electric circuit was completed. The position of the top of the column of tin in the stem could thus be ascertained and the stem divided up in the same manner as a thermometer. Dufour many years ago suggested a thermometer of tin in a silica envelope, but the instrument never came into practical use, and the graphite enclosure is an undoubted improvement. Dr. Northrup has found that molten tin does not give off vapour at 1700° C., and proposes to use his instrument up to this or even higher temperatures. Mr. C. R. Darling suggested a thermo-electric pyrometer in which one or both of the members of the couple might melt without breaking the circuit. As shown by Mr. A. W. Grace and Mr. Darling, the thermo-electric properties of metals in general are unchanged by fusion, and hence cheap metals, such as tin or copper, might be used to measure temperatures of 1500° C. or more, as their boiling points usually exceed 2000° C.

An excellent feature of the meeting was an exhibition in the room of pyrometric apparatus of all kinds. Included in these was the original tapered gauge used by Josiah Wedgwood for measuring the contraction of his clay cylinders, by means of which the science of high-temperature measurement was founded. The modern productions of British makers are highly satisfactory, and this young but flourishing industry has undoubtedly a great future in front of it. Special mention may be made of an automatically controlled furnace, on the principle devised by Mr. R. P. Brown, of Philadelphia. The control is effected by means of a thermo-electric pyrometer inserted in the furnace, the indicator of which is provided with two stops, which may be set in any position, one on either side of the pointer. To control a furnace to within 5° above or below a given temperature, the stops are set at 5° on either side of the number on the indicator. The pointer of the indicator is depressed periodically by means of clockwork, and when touching either stop an electric circuit is completed which actuates a relay. If touching the lower stop, the effect is to cut out an external resistance from an electric furnace, or to open wider the tap of a gas supply in a gas furnace, whilst when in contact with the higher stop resistance is added or the gas supply checked. There appears to be no good reason why large furnaces should not be similarly controlled, and the saving in fuel and labour effected should soon cover the cost of the apparatus.

The success of the discussion, in which makers of pyrometers, representatives of various industries, and scientific men were able to compare notes, suggests that meetings of this kind are desirable in connection with the application of science to manufacturing processes, and cannot fail to act as a stimulus to all concerned.

HEREDITARY CHARACTERS IN RELATION TO EVOLUTION.[1]

II.

(1) FIRST, then, what are the facts as to numerous finely graded variations in a single unit factor? Here we have certain remarkable data as to the eye-colour of Drosophila—data that are of great interest with relation to the nature of evolutionary change. This fruit fly has normally a red eye. Some years ago a variation occurred by which the eye lost its colour, becoming white, a typical mutation. Somewhat later, another variation came, by which the eye colour became eosin. By those wonderfully ingenious methods which the advanced state of knowledge of the genetics of Drosophila have made possible, it was determined that the mutations white and eosin are due to changes in a particular part of a particular chromosome, namely, of the so-called X-chromosome, or chromosome I. And further, it was discovered that the two colours are due to different conditions of the same *locus* of the chromosome; in other words, they represent two different variations of the same unit. Moreover, the normal red colour represents a third condition of that same unit. And now, with the minute attention paid to the distinction of these grades of eye colour, new grades begin to come fast. Up to date we know from the mutationists' own studies of Drosophila that a single unit factor presents seven gradations of colour between white and red, each gradation heritable in the usual Mendelian manner. These grades are the following:—(1) red; (2) blood; (3) cherry; (4) eosin; (5) buff; (6) tinged; (7) white. Considering that the work on Drosophila has been going on only about seven or eight years, this is remarkable progress toward a demonstration that a single unit factor can present as many grades as can be distinguished; that the grades may give a pragmatically continuous series. The extreme selectionist asks only a little more than this.

Besides showing that a unit factor may thus exist in numerous minutely differing grades, this case shows that a heritable variation may occur so small as to be barely detectible. Although the variations do not usually occur in this way, the case presents the conditions which would allow of a gradual transition from one extreme to the other, by means of numerous intermediate conditions. In a population in which were occurring such minute changes as are here shown to be possible, we could get by selection such a continuous series of gradations as Castle describes in his rats.

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[1] Abridged from an address by Prof. H. S. Jennings. Continued from p. 198.

(2) But, as we have seen, the mutationists reject the view that the changes in the coat colour of the rat are due to alterations in a singe unit factor; they explain this and other cases of the effectiveness of selection on a single character by *multiple modifying factors.* Accepting again their contention, the question is shifted to the nature of such factors.

Our direct experimental knowledge of these "modifying factors" is scanty. We find data as to certain known modifying factors by one of the workers on Drosophila, Bridges (1916), in his recent important paper on non-disjunction of the chromosomes.[7] Bridges found a factor the only effect of which was to lighten the eosin colour in a fly with eosin eyes; this factor, indeed, nearly, or quite, turns the eosin eye white. Another factor has the effect of lightening the eosin colour a little less, giving a sort of cream colour. A third factor dilutes the eosin colour not so much. In addition to these, Bridges has discovered *three other* diluters of the eosin colour, and another factor the only effect of which is to modify eosin in the direction of a darker colour. None of these factors has any effect save on eosin-eyed flies. These things add tremendously to our gradations in eye colour. We had already been furnished seven grades, from white to red; now we have seven secondary grades within a single one of these seven primary grades. These seven new grades are not located in the same unit factor as are the seven primary ones; their loci are in other chromosomes (or possibly in other parts of the same chromosome).

Here again, then, we have minutely differing conditions of a single shade of colour, brought about by seven modifying factors. Bridges makes the following remark concerning them :—

"A remarkably close imitation of such a multiple case as that of Castle's hooded rats could be concocted with the chief gene eosin for reduced colour, and these six diluters which by themselves produce no effect, but which carry the colour of eosin through every dilution stage from the dark yellowish pink of the eosin female to a pure white."[8]

Now this is an extremely interesting statement, one that must arouse the keen interest of the student of the method of evolution. In Drosophila we could get the same sort of graded results that Castle does with his rats, only in Drosophila this is by means of multiple modifying factors, whereas Castle believes that in the rat it is by actual alterations of the hereditary constitution!

But what are these modifying factors? And here we come to the astonishing point. *These modifying factors are themselves alterations in the hereditary constitution.* Bridges leaves no doubt upon this point. He lists and describes them specifically as mutations; as actual changes in the hereditary material.

Where, then, is the difference in principle between the condition in Drosophila and that in the rat? In Drosophila there occur minute changes in the germinal material, such as to give, so far as our present imperfect knowledge goes, seven diverse grades of a colour which is itself only one grade of another series of seven known grades. By means of these graded changes one could obtain, by the mutationist's own statement, the continuously graded results which selection actually gives. What more can the selectionist ask?

The mutationist thinks of all these numerous grades as, after all, essentially discontinuous, as a series of steps so minute that the difference between one and the next one is not detectible. His opponent, on the other hand, perhaps thinks of the series as actually continuous. But when steps become so minute as to be beyond detection, the question whether they exist becomes metaphysical.

To put the case in brief, if the mutationists are to show that the existence of multiple modifying factors has any bearing on the general question of the effectiveness of selection, they must show that such factors are not themselves minute changes in the hereditary constitution. Not only have they made no attempt to do this, but in the only well-examined cases they state squarely that such factors are indeed alterations in the hereditary constitution.

For the inheritance of such factors as Mendelian units, of course absolutely nothing is required save that the location of the change is in a chromosome. No particular degree of magnitude, no unity of any other kind is required.

But there remains one point brought out by the mutationists which is of great importance to the student of the method of evolution. While they must admit, by their own account, that all these grades occur, they, of course, point out that the changes do not occur in a continuous series. In the eye of Drosophila variation may occur from red to white directly, without any transitional stages; or from any grade to any other; the continuous scale is obtained only by arranging the steps in order. Therefore, it is maintained, evolution may have occurred by such large steps, not by continuous gradations.[9] This is, of course, a matter deserving of serious consideration. But certain other points must be considered also. First, the very facts known for Drosophila show that there is nothing to prevent a passage from one extreme to the other by minute changes, just as is held to occur by the palæontologists and selectionists, although change by large steps occurs also. Secondly, in such cases as the eye colour of Drosophila we are dealing with characters that are already highly developed. We know, for example, that this particular character is formed by the co-operation of many separate parts of diverse chromosomes; it is a highly complex product of evolution. Now, we find that one or another of these parts may suddenly cease to perform its function, so that the red colour is not completely formed; there is a sudden change in it; or it may disappear entirely. But is this, after all, strong evidence that in the original production of this complex character with its numerous underlying functional parts, there was the same change by sudden large steps? Indeed, is it not rather true that such destructive changes in a fully formed character could not be expected to throw light on how that character was built up?

To sum up, it appears to me that the work on Drosophila is supplying a complete foundation for evolution through selection of minute gradations. The so-called "multiple allelomorphs" show that a single unit factor may thus exist in a great number of grades; the "multiple modifying factors" show that a visible character may be modified in the finest gradations by alterations in diverse parts of the germinal apparatus. The objections raised by the mutationists to gradual change through selection are breaking down as a result of the thoroughness of the mutationists' own studies. The only outstanding difficulty is the fact that large changes occur as well as small ones; this seems perhaps due to the fact that we are witnessing the disintegration of highly developed apparatus in place of its building up.

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[7] Bridges, 1916, p. 148. (See Bibliography.)

[8] *Ibid.*, p. 149. (See Bibliography.)

[9] See particularly the discussion of this point in Morgan, 1916, pp. 7-27. (See Bibliography.)

In all this, except the last point, the work on Drosophila is in agreement with my own observation of gradual variation in Difflugia, with Castle's similar results on the rat, and with the conclusions of palæontologists as to the gradual development of the characteristics of organisms in past ages.

But there is one point in the palæontological conclusions which is not in agreement with the experimental and observational results on existing organisms; this I wish to notice briefly. Osborn sets forth that in following given stocks from earlier to later ages, characters arise from minutest beginnings, and pass by continuous gradations to the highly developed condition; these developing characters do not show random variations in all directions, but follow a definite course, which might seem to have been in some way predetermined. And this is emphasised by the fact that the same sorts of characters (horns, for example) may arise independently, at different ages, in diverse branches of the same stock, and each follow in later ages the same definite course of development. Evolution is characterised by Orthogenesis, as this phenomenon has sometimes been called.

Now it appears to me that we do not observe this in the present-day experimental work; by selection we can move in more than one direction. There is no indication, so far as I can see, that the variations push in one determinate direction only. Examining the palæontological summaries further as regards this, we find that diverse courses are followed by given characters, in diverse branches of a given group.

A second point which Osborn sets forth is deserving of particular attention. He states, in agreement with Waagen, that in any given geologic stratum, we do find, in addition to characteristics that are in the line of determinate descent, other variations from this line, which are of the sort that constitute what we call at the present time varieties; things that are like the diverse races of Difflugia in my own work. But, say Osborn and Waagen, there is a great difference in principle between these and the others, for those which are in the determinate line of progress persist into the next geologic stratum, while the mere varieties do not. The persistent changes were called by Waagen mutations (in a sense somewhat diverse from that in which the word is used by de Vries).

Osborn expresses the opinion that these "varieties" may be merely non-heritable modifications.[10] But in our present geologic period we find just such diverging forms, in great number, and we find that their peculiarities *are* heritable. There is, then, no reason for supposing that these variations were not heritable in earlier geological periods; there must have been many races heritably diverse, just as there are now; and these are what Waagen called varieties.

Now, since this is so, the only difference between Waagen's mutations and his varieties is that the former persisted and the latter did not. But this tells us nothing whatever about why the latter did not. It is perfectly possible, so far as these facts go, that it was a matter of selection by external conditions; many diverse stocks were present, on an equal footing; some were destroyed, others were not. The conditions described by the palæontologists support strongly the theory of evolution by gradual change, but I cannot see that they tend to establish the view that variations show a tendency to follow a definite course, as if predetermined. The palæontologists appear rather to report precisely the conditions which we are bound to find if evolution occurs through the guidance of natural selection operating on a great number of diverse variations, the typical Darwinian scheme.

There is one other point, made by Bateson (1914), in his presidential address before the British Association, and further developed by Davenport (1916) in a recent paper: the proposition, namely, that since practically all observed variations are cases of loss and disintegration, we are driven to suppose that evolution has occurred by loss and disintegration. Davenport combines this idea with the theory that these disintegrating variations follow a definite course, predetermined in large measure by the constitution of the disintegrating material.

There are two points worth consideration in dealing with this theory. The first is one of fact; although it is true that many of the so-called mutations appear to be cases of loss and disintegration, yet there is no indication that this is the case in such effects of selection as have been described by Castle and myself; variations are not limited to any particular direction. Secondly, it appears to me that this conclusion—that because the variations we see are cases of loss and disintegration, therefore evolution must have occurred by loss and disintegration, involves an error in logic, which makes it unworthy of serious consideration.

To summarise, then, what I have obtained from experimental work combined with a survey of the work of others, the impression left is as follows:—

(1) Experimental and observational study reveals that organisms are composed of great numbers of diverse stocks differing heritably by minute degrees.

(2) Sufficiently thorough study shows that minute heritable variations—so minute as to represent practically continuous gradations—occur in many organisms, some reproducing from a single parent others by biparental reproduction.

(3) The same thing is reported from palæontological studies.

(4) On careful examination we find even that the same thing is revealed by such mutationist work as that on Drosophila; single characters exist in so many grades due to minute alterations in the hereditary constitution as to form a practically continuous series.

(5) It is *not* established that heritable changes must be sudden large steps; while these may occur, minute heritable changes are more frequent.

(6) It is *not* established that heritable variations follow a definite course as if predetermined; they occur in many directions.

(7) It is not established that all heritable changes are by disintegration; although many such do occur, they cannot be considered steps in progressive evolution from the visibly less complex to the visibly more complex.

Evolution according to the typical Darwinian scheme, through the occurrence of many small variations and their guidance by natural selection, is perfectly consistent with what experimental and palæontological studies show us; to me it appears more consistent with the data than does any other theory.

Bibliography.

W. Bateson (1914), Address of the President of the British Association for the Advancement of Science, *Science,* vol. xl., pp. 319–33. C. B. Bridges (1916), Non-disjunction as proof of the chromosome theory of heredity, *Genetics,* vol. i., pp. 1–52, 107–63. W. E. Castle (1915), Mr. Muller on the constancy of Mendelian characters, *Amer. Nat.,* vol. xlix., pp 37–42. W. E. Castle (1915 *a*), Some experiments in mass selection, *Amer. Nat.,* vol. xlix., pp. 713–726. W. E. Castle (1916), Can selection cause genetic change? *Amer. Nat.,* vol l., pp. 248–56. W. E. Castle (1916 *a*), Further studies of piebald rats and selection, with observations on gametic coupling, Carnegie Institution, Washington, Pub. 241, part iii., pp. 161–92. W. E.

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[10] Osborn, 1915, p. 225. (See Bibliography.)

Castle (1916 *b*), Genetics and Eugenics, Cambridge, pp. 353. W. E. Castle (1917), Piebald rats and multiple factors, *Amer. Nat.*, vol. li., pp. 102–14. W. E. Castle and J. C. Phillips (1914), Piebald rats and selection: an experimental test of the effectiveness of selection and of the theory of gametic purity in Mendelian crosses, Carnegie Institution, Washington, Pub. 195, pp. 56. C. B. Davenport (1916), The form of evolutionary theory that modern genetical research seems to favour, *Amer. Nat.*, vol. l., pp. 449–65. A. L. and Mrs. A. C. Hagedoorn (1914), Studies on variation and selection, *Zeitschr. f. ind. Abst. u. Vererb.*, vol. xi., pp. 145–83. A. L. and Mrs. A. C. Hagedoorn (1917), New light on blending and Mendelian Inheritance, *Amer. Nat.*, vol. li., pp. 189–92. R. R. Hyde (1916), Two new members of a sex-linked multiple (sextuple) allelomorph system, *Genetics*, vol. i., pp. 535–80. H. S. Jennings (1908), Heredity, variation, and evolution in Protozoa: II., Heredity and variation of size and form in Paramecium, with studies of growth, environmental action, and selection. Proc. Amer. Philos. Soc., vol. xlvii., pp. 393–546. H. S. Jennings (1909), Heredity and variation in the simplest organisms, *Amer. Nat.*, vol. xliii., pp. 321–37. H. S. Jennings (1910), Experimental evidence on the effectiveness of selection, *Amer. Nat.*, vol. xliv., pp. 136–45. H. S. Jennings (1911), Pure lines in the study of genetics in lower organisms, *Amer. Nat.*, vol. xlv., pp. 79–89. H. S. Jennings (1916), Heredity, variation, and the results of selection in the uniparental reproduction of Difflugia corona, *Genetics*, vol. i., pp. 407–534. E. C. MacDowell (1915), Bristle inheritance in Drosophila, *Journ. Exper. Zool.*, vol. xix., pp. 61–97. E. C. MacDowell (1916), Piebald rats and multiple factors, *Amer. Nat.*, vol. l., pp. 719–42. T. H. Morgan (1916), A critique of the theory of evolution, Princeton University Press, pp. 197. T. H. Morgan (1917), An examination of the so-called process of contamination of genes, *Anat. Record*, vol. xi., pp. 503–4. H. F. Osborn (1912), The continuous origin of certain unit characters as observed by a palæontologist, *Amer. Nat.*, vol. xlvi., pp. 185–206, 249–78. H. F. Osborn (1915), Origin of single characters as observed in fossil and living animals and plants, *Amer. Nat.*, vol. xlix., pp. 193–239. H. F. Osborn (1916), Origin and evolution of life upon the earth, *Scientific Monthly*, vol. iii., pp. 5–22, 170–90, 289–307, 313–34, 502–13, 601–14. Raymond Pearl (1915), Seventeen years' selection of a character showing six-linked Mendelian inheritance, *Amer. Nat.*, vol. xlix., 595–608. Raymond Pearl (1916), Fecundity in the domestic fowl and the selection problem, *Amer. Nat.*, vol. l., pp. 89–105. Raymond Pearl (1917), The selection problem, *Amer. Nat.*, vol. li., pp. 65–91. Edna M. Reeves (1916), The inheritance of extra bristles in *Drosophila melanogaster*, Meig, Univ. Calif. Pub. Zool., vol. xiii., pp. 495–515. S. R. Safir (1916), Buff, a new allelomorph of white eye color in Drosophila, *Genetics*, vol. i., pp. 584–90. A. H. Sturtevant (1917), An analysis of the effect of selection on bristle number in a mutant race of Drosophila, *Anat. Record*, vol. xi., pp. 504. C. Zeleny and E. W. Mattoon (1915), The effect of selection upon the "bar-eyes" mutant of Drosophila, *Journ. Exper. Zool.*, vol. xix., pp. 515–29.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

IT is proposed by the governors of the West Ham Municipal Central Secondary School to call the institution "The Lister School," to perpetuate the association of Lord Lister with the borough of West Ham.

THE annual meeting of the Association of Public-School Science Masters will be held on Tuesday and Wednesday, January 8 and 9, at the City of London School, under the presidency of Sir Ronald Ross, who will give an address on "Observations on the Results of our Present System of Education." The subjects to be discussed during the meeting are:—Examination or inspection as a test of science teaching, G. F. Daniell; Compulsory science in university entrance examinations, O. H. Latter; Subsidiary subjects in university scholarships examinations, H. de Havillard; Descriptive astronomy in the "science for all" course, Rev. A. L. Cortie; and Map reading as a school subject, V. S. Bryant.

A SCHOLARSHIP designated the "Institution of Naval Architects Scholarship in Naval Architecture" will be offered for competition among students of the institution in 1918. All students (being British subjects) who have been elected at or before the annual general meeting of the institution (March 20, 1918) will be eligible for this scholarship, subject to the conditions named below. The scholarship is of the annual value of 100*l.*, and is tenable for three years, provided that they are not less than eighteen or more than twenty-one years of age on March 1, 1918, and at that date have been continuously employed for at least two years upon naval architecture or marine engineering. Candidates for the scholarship must forward a written application to the secretary of the Institution of Naval Architects, 5 Adelphi Terrace, London, W.C.2, to reach him not later than January 15, 1918.

MR. FISHER is still hopeful that the passage of his Education Bill into law will not be postponed indefinitely. Speaking at Swindon on November 10, he said that, though the pressure of Parliamentary business may render it impossible for the Government to proceed with the Bill this session, it must not be supposed that the Bill will therefore be discarded. The Government intends to proceed with the measure at the earliest possible opportunity, always, of course, assuming that the complexion of European events permits Parliamentary attention to be bestowed on domestic legislation. So important is it to the nation that the education of those on whom its industrial efficiency depends shall be extended and improved that we are confident, if the Government is really in earnest, there will be no insuperable difficulty about finding the time at least to pass the educational clauses of the Bill. The meeting at which the President of the Board of Education spoke passed a resolution approving the Bill and protesting against any delay in securing its passage through Parliament.

THE subject of University Representation in Parliament was before Committee of the House of Commons on November 8, in connection with the Representation Bill. Sir Philip Magnus's amendment, giving separate representation with one seat to the University of London and two seats to the group composed of Durham, Manchester, Wales, Liverpool, Leeds, Sheffield, Birmingham, and Bristol, was adopted on a division by a majority of 128 (162 for, 34 against). The amendment was supported by speeches also from Sir William Collins, Mr. Burdett-Coutts, Mr. Macmaster, Mr. Boyton, and Col. Greig, and accepted by the Home Secretary (Sir George Cave). Sir Philip Magnus laid stress on the peculiar constitution, character, and work of the University, and pointed out the practical objections to the large group, including London, proposed by the Bill. This point was emphasised also by Sir William Collins, who said that the three representatives of the proposed group would speak with no sense of individuality, and would represent nothing but a fortuitous and heterogeneous concourse of academic atoms. Sir George Cave said he did not think the Speaker's Conference intended to put a slight upon the University of London, but had in mind the